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The Cybernetic "General Model Theory": Unifying Science or Epistemic Change?

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With the marginalization of cybernetics, efforts to develop a universal epistemological method ceased as well. But the question remains open as to whether cybernetics contributed to the reconceptualization of the model and the popularity of scientific modeling since the mid-twentieth century. The present study approaches this question using the example of the general model theory of the German cyberneticist Herbert Stachowiak. Although this theory failed to produce a unifying and common model concept, its characteristics point toward a change in epistemological positions that is important for today's scientific practice and also anticipated recent developments in the philosophy of science.

1. Introduction

"The term 'model' has become fashionable" (Hesse 1967, p. 354). What Mary Hesse characterized in the mid-1960s as a trend in logic, mathematics, and the natural sciences, applies today in general for a broad spectrum of disciplines. Today models appear to be of "extraordinary importance" (Gähde and Hartmann 2013, p. 1) compared to the first half of the twentieth century, when models (in contrast to theories) were neither mentioned nor contemplated, either generally in scientific publications or specifically in the philosophy of science (see Bailer-Jones 2009, p. 18; more explicitly Bailer-Jones 1999, p. 23). It is even assumed that models are "the key to science" (Franck 2004) and that today's science is largely "model based" (Kuorikoski and Marchionni 2015, p. 381).

Put in general terms, models play a crucial epistemological role: The idea behind scientific modeling is to represent and increase information. The core purpose for using models is the simplification, visualization, idealization, modification, or hypothetical realization of phenomena together with the aim making the latter easier to understand. Models are imagined,

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built, empirically or hypothetically tested, compared, and used as the basis of more adequate future models. But why did the concept of the model become significantly more important in the second half of the twentieth century? What fostered this transformation and how did it evolve? As highlighted in two special issues of *Perspectives on Science* (vol. 21, no. 2, 2013; vol. 23, no. 4, 2015), historians and philosophers of science have recently dedicated more attention to such questions, debating not only why and in what disciplines the model concept has frequently appeared, but also the practice and significance of modeling. To be sure, more powerful computing led to better modeling techniques and visualization methods and also facilitated simulations of non-accessible objects of inquiry (see Winsberg 2010; Morrison 2015). However, technological advances alone cannot fully explain the growth of the model's importance. This article seeks to join the discussion about the relevance and abundance of models, pursuing the thesis that their popularity since the mid-twentieth century was also due to a reconceptualization of the model itself, which was linked to the model's change in functions. Both together also reflect a transformation of epistemological positions during this period.

To provide a background for this argument, we first need to outline the long history of the creation and use of models, showing that the model concept was never static. "Thinking in models" is older than the term itself; for a long time, religious parables, for example, served in a sense as models to represent abstract actions. However, as far as we know, the word "model" only began to be increasingly used since the Italian Renaissance, originating in architecture. At the time, it was interpreted similarly to today's understanding of the words "illustration," "example," or "replica" (Müller 1980, pp. 205–06). According to Max Jammer, "model" only began to be used as a special scientific term ("*terminus technicus*") starting in the mid-nineteenth century. But he notes that we can find precursors of this development as early as the emergence of modern science around 1600. Francis Bacon, for example, viewed the experimental situation as a replication—and thus a model—of physical reality. Early-modern corpuscular and kinetic theories followed directly from observation and the building of models (Jammer 1965, pp. 167–9). Hence models were supposed to illustrate empirical phenomena through replication and representation, as machines imitating nature (such as Jacques de Vaucanson's "digesting duck" of 1739). Even before the term "model" became widely established, mechanical explanations were used to improve our understanding of natural entities. Thus, the prevailing model concept of this epoch was the *mechanical model* (see Bailer-Jones 2009; Müller 2009; Gelfert 2016).

Toward the end of the nineteenth century, new scientific and epistemological positions emerged, thereby creating new impulses for the reconceptualization of the model, two of which warrant emphasis here. First, the early critique of positivism—and therefore also of the real-world validity of models—led to the denial of the truth value of models. Ernst Mach, for example, interpreted them not as illustrations but rather as methodological means for expedient simplification (Jammer 1965, p. 171). The rise of instrumentalism may not have eliminated the model's representational function, but this function was devalued, whereas the function of simplification gained importance.

Second, with the mathematization of various branches of science during the first third of the twentieth century, the sciences embarked upon a radical and sustained reorientation, which also meant that the mechanical models of classical physics lost their preeminence (Bailer-Jones 2009, p. 21–6). According to Ernst Cassirer (1929), science first became systematic by becoming, strictly understood, a symbolic language. Changes to the nature of the model reflected this transformation of the conception of science: advances in abstract mathematics led to the model's semantic modification. The *formal model* of mathematical logic emerged at the intersection of algebra, non-Euclidean geometry, deductive logic, and set theory, which was formulated in the early twentieth century. They were prerequisites for mathematical model theory, developed in large part by Alfred Tarski and based on his earlier semantic truth definition (Bourbaki 1994, pp. 22–3; Müller 1965, p. 154). The formal mathematical model subsequently became an important part of the methodology of the exact sciences. It rapidly spread into numerous application areas, such as statistics and data analysis, where the model represented a set of numbers on the basis of what was construed as a superordinate formal logic. The shift of dominance from the mechanical model of the nineteenth century to the formal model is just *one*—albeit key—indication that the concept of the model was being continually redefined and that its functions varied.

The deductive, formally logical operation with symbols threw competing model applications into question, triggering repercussions for the social and human sciences and especially for behavioral science. These fields, too, featured long traditions of using models to explain invisible bodily processes (for example, blood circulation and thinking) through replicas and simulations. Long before the term "model" became resoundingly popular in the mid-1960s, medicine and also behavioral science were based on mechanical model concepts, or, in other words, "the practice of using machinery to approximate nature" (Riskin 2003, p. 98). In addition, psychology in particular was already using heuristic structures in the sense of a hypothetical "as if" at an early stage (apparent in Sigmund Freud's hydraulic model) alongside classical models borrowed from architecture (for example, the "body model"). These heuristic models are functional, that is, in order to represent mental processes, paths are used that graphically represent the direction, influence, and magnitude of one variable which influences another variable, whereas gradations within a diagram often illustrate maturation or learning processes (Herzog 1984, p. 92). Functional perspectives require us to address *models as concrete entities*, which are constructed for epistemic purposes.

The heuristic method is hardly in a position to fully depict the real world; at the same time, it is not identical with formal logic. But the mathematical principle of non-contradiction puts pressure on heuristics; more precisely, by the mid-twentieth century formal logic had developed into an authoritative reference point for widely ranging fields of knowledge. Thus, according to Peter Achinstein, advocates of logical empiricism (who predominantly shaped scientific theory at the time) understood the meaning of the model "in a single sense," namely, as exclusively following mathematical logic (Achinstein 1964, p. 328). Formalistic-deductive positions were even advocated in the practice of social and human sciences—from psychology to linguistics ("structuralism")—as evidenced, for example, by efforts to grasp language development by means of "preformulated theoretical conceptions" (Hartmann 1965, p. 371). According to Hunter Heyck, given the assumption that mathematics was the "language of discovery," in the mid-twentieth century there was also "no question that a reformed behavioral science would be mathematical" (Heyck 2015, p. 35). The American psychologist Richard C. Atkinsons maintained the position, for example, that human learning could be formally modeled by means of mathematics, and thus generally explained. Atkinson noted that, admittedly, a few behavioral scientists voiced doubts that this would ever be possible, but "similar objections were raised to mathematical physics as recently as the late 19th century, and only the brilliant success of the approach silenced opposition" (Atkinson 1961, pp. 46–7). This led him to conclude that, thanks to the mathematical concept of the model, psychology would soon be able to register similar successes.

This outline points toward the fact that the position and use of formalism was highly charged with meaning. At the same time, the outline clearly shows that—contrary to its seemingly universal and timeless claims of validity—various conceptualizations of the model have competed against each other for interpretive supremacy. Most notably, in the 1960s Mary Hesse presented the idea that (old) mechanical models serve as analogues of the object of inquiry. By recognizing analogy as a means to compare known with unknown objects, and by arguing that this process was crucial for scientific reasoning (Hesse 1966), she qualified the primacy of formal models. This paper will argue that the rivalry of different concepts did not result in a common terminology, rather, it has ultimately meant that function attributions of the model concept have increased.

As shown at the outset, models also appear important today; moreover, the term is widely dispersed among various different disciplines from mathematics to the natural, social, and human sciences, and to the humanities (Morgan and Grüne-Yanoff 2013, p. 144). According to Hunter Heyck (2015, pp. 24–5), however, since the 1970s not only is the model concept being used more often, the types of models have increased as well. Thus, at that time there seems to have been *a new turning point* in the history of the model. This article attempts to show that with the so-called cognitive turn around 1970, the functions of the model multiplied again; in other words, this article seeks to work out how the model concept changed due to this epistemological transformation.

In doing so, this article joins with Daniela Bailer-Jones, who structured the "shifts of interests regarding models" since 1950 into three epochs: a popularization phase characterized by the initial definition of concepts, followed in a second phase by a shift from "formal to functional characterization," which in a third phase was complemented by the "cognitive perspective on scientific modeling" (Bailer-Jones 1999, p. 35). The latter implies that models are comparable to cognitive aids, or: "Models [are no longer viewed] exclusively in terms of their role in science, but in terms of their role for human cognition" (ibid., pp. 37–8). Tarja Knuuttila made a similar argument concerning contemporary cognitive science, according to which knowledge is bound to the ability to (intentionally) construct (Knuuttila 2005, p. 1266). Accordingly, human powers of imagination are nowadays seen as playing a central role in the conceptualization of our knowledge, and this process of internal construction finds expression in the medium of the model. This means that the model is not a "representation" of the real world but rather an "epistemic tool" (Boon and Knuuttila 2008).

The substantive consequences of the cognitive turn for the model concept have thus far hardly been elucidated (e.g., Kuorikoski and Marchionni 2015, p. 385n). Therefore, the following three sections shall use a case study to delve into the transition between the second ("functional") and third ("cognitive perspective") phases, focusing on a work that has previously received little attention in the debate regarding the model: the *General Model Theory (Allgemeine Modelltheorie)* of 1973. The author of the text was the German cyberneticist Herbert Stachowiak (1927–2004). Although his scholarly estate allows few conclusions about the preliminary work on his model theory, it nonetheless reveals his intention to derive the definition of the model from its "actual use," which for Stachowiak (1973, p. 1) was equivalent to empiricism. Precisely because he applied his method inductively to the linguistic usage of his contemporaries, his work thoroughly documented the transformation of the model concept.

Roland Müller notes that Stachowiak developed one of the most elaborate classifications of the model, which then was "widely ignored" (Müller 2004, p. 256). The fact that it was never translated is a major reason why the general model theory is little known outside the German-speaking world (Ritchey 2012, p. 3). Nonetheless, it provides an informative source for the aforementioned transformation of the model concept. On the one hand, it allows us to trace why models have become so important for contemporary scientific practice; on the other hand, it constitutes a precursive development of recent discussions in the philosophy of science that equate models with "epistemic tools." In the general model theory, this shift of perspective from the model as product to the model as instrument reads almost paradigmatically.

Stachowiak had received his doctorate in mathematics in West Berlin during the post-war period, but dedicated his attention to issues pertaining to scientific theory, morality, psychology, and educational planning, turning increasingly to philosophy, particularly pragmatism. Working first as a night school director, he established his footing in academia relatively late. In 1973 he was appointed to the professorial chair for scientific and planning theory in Paderborn. His biography as an academic all-rounder is emblematic for cybernetics, a field that was highly influential but conceptually almost impossible to grasp.

According to Stachowiak, the model's increased importance since the mid-twentieth century can be explained by the advances of formalism and the deductive method, and was also founded in the "cybernetic movement" (Stachowiak 1983, p. 11). *General Model Theory* is a contribution to cybernetic thought in the context of Germany's post-war history. Thus, the first section below not only presents the cybernetic concept of the model but also historicizes the specificity of German cybernetics. The second section focuses on the development of the general model concept. Using these characteristics as a basis, the third section then explicates a consequential reformulation of epistemological positions.

2. Bridging Disciplinary Boundaries with the Model

Cybernetics—the term was coined by mathematician Norbert Wiener—emerged from the United States in the mid-twentieth century. Although originating in technical engineering problems, it claimed to form the gravitational center of various scientific and technical disciplines and thus to be a universal science with a common unifying language (Bowker 1993). To this end, fragments of knowledge from mathematics, physics, and linguistics brought to the United States through the emigration of many researchers were combined with American pragmatism and behavioral science (Lafontaine 2004, 2007). Closely tied to this conglomerate was the claim to bundle knowledge into models that were valid at an explicitly interdisciplinary level, based on concepts such as feedback, signal, information, and entropy. Modeling was an important method of cybernetics: abstraction from the concrete in conjunction with a focus on commonalities in order to arrive at comparable data was programmatic. Visual aids, metaphors, and diagrams therefore formed the core of cybernetic language (Hagner 2006; Hörl 2008). On the one hand, they facilitated interdisciplinary translations; on the other hand, they were tools for communicating with the public.

Two aspects of the cybernetic model are striking. First, it is a functional model concept; thus, it concentrates on processes that are inferred by means of reduction, or, in the words of two founders of cybernetics: "abstraction consists in replacing the part of the universe under consideration by a model of similar but simpler structure" (Rosenblueth and Wiener 1945, p. 316). Second, the cybernetic model builds on the principle of analogy in the belief of thereby facilitating progress:

> The test of the usefulness of this new science, as that of any science, must be its results. … That is to say, *the analogies* which cybernetics may suggest between communication channels or control processes in machines, nerve systems, and human societies must in turn suggest new observations or new experiments. (Deutsch 1951, p. 240; emphasis added)

Conclusion by analogy was the preferred *modus operandi* of cybernetics. Moreover, the orientation of cybernetics toward results clearly points to the fact that cybernetics reestablished and reinterpreted instrumentalism in the post-war period. Despite this hereditary relationship to the scientific theory of instrumentalism, cybernetics was perceived within and outside of science as a renewal movement. Its attraction derived from the Allied victory in the Second World War, achieved in part by involving researchers who tested their theories and calculations in practice (see Galison 1994). Precisely because wartime research was geared toward application, instrumentalism received a boost.

The second-generation cybernetic theorist Anthony Wilden, who explicitly elevated cybernetics to the "science of models," located the origins of cybernetics in technology, but noted that from here its transfer was pursued to non-technical applications. According to Wilden, models are an abstract vocabulary that can be applied to any particular object of study. Their use is associated with the hope of unifying scientific cultures and "of introducing new order into the currently disordered state of discourse of science" (Wilden 1979, p. 9–11).

The idea of an application-related science became increasingly popular on both sides of the Cold War ideological divide. In particular, the allures of reform efforts based on the rationality concept of praxis-oriented science shined forcefully onto the politically and culturally disoriented environment of post-war Germany. The project to reorganize the sciences met with the need for a new start—the objectifying, techno-optimistic program of cybernetics offered an opportunity to "veer away from the repertoire of German traditions of thought" (Hagner 2008, p. 52). For contemporaries, it promised a "path to a new unity of the sciences" (Steinbuch 1962) and was declared to be the method "for integrating our findings about society and man" (Klaus 1967, p. VII) or even an "umbrella science" (Lutz 1970).

In the context of widespread enthusiasm for United States—that is, the appropriation during the post-war period of American ideas, a process that differed from the previous "European-American exchange of ideas" (Doering-Manteuffel 2011)—the transfer of cybernetics was virtually unidirectional, with the exception of supportive contributions by the philosopher Gotthard Günther and criticisms by Martin Heidegger. Awareness of the German offshoot of cybernetics, associated with names such as Max Bense, Georg Klaus, Karl Steinbuch, and Helmar Frank, barely reached beyond the national borders. However, the inner German border did not pose an obstacle for the basic assumptions of cybernetics.

The logician Georg Klaus played a major role in the reception of cybernetics in East Germany, where it evolved into a dialectic-materialist method (Segal 2004, p. 234). Notably important for West Germany was the engineer Hermann Schmidt, creator of the General Regulation Theory *(Allgemeine Regelungskunde)* (see Dittmann 1999; Bissell 2011). Schmidt, too, adopted the cybernetic claim of universality, expressed particularly in its modeling method's search for analogies. He maintained: "Among the secure possessions of cybernetics is the technical-organic feedback analogy, toward which the cybernetic collaboration of a growing number of non-technical sciences, for example, biology, physiology, sociology, and philosophy, is orienting itself" (Schmidt 1966). In Germany, too, universal models were supposed to be used to bridge disciplinary boundaries.

In both East and West Germany, efforts to elaborate a general definition of the model concept were undertaken with explicit reference to cybernetics. In East Germany, Klaus-Dieter Wüstneck published an article in 1963 entitled "On the Philosophical Generalization and Determination of the Model Concept" ("Zur philosophischen Verallgemeinerung und Bestimmung des Modellbegriffs") in which he found that the "rapid development and expansion of cybernetics" was invigorating the method of modeling, but no generalization was available yet (Wüstneck 1963, p. 1504). How the West German Herbert Stachowiak made his way to cybernetics remains unknown; nor do we know whether he was familiar with Wüstneck's text when he drafted his article "Thoughts on a General Theory of Models" ("Gedanken zu einer allgemeinen Theorie der Modelle"). However, we know that he was linked into a network of scientists, technicians, and industrialists who in the 1960s met weekly in West Berlin for "cybernetic tea parties" and regularly invited Hermann Schmidt as a guest speaker (Hof 2016, p. 82). As part of this circle that used cybernetic models to understand human learning, Stachowiak developed a "psycho-structural model," which he presented at a conference in 1964 and subsequently published in 1965 as a monograph entitled *Thinking and Cognition in the Cybernetic Model (Denken und Erkennen im kybernetischen Modell)*. He integrated within this model a concept of learning (called "learning matrix") taken from the IT pioneer Karl Steinbuch and the human cyberneticist Helmar Frank, linking this "learning matrix" to a concept of motivation (Stachowiak 1965a). At the same time, he worked out a definition of the model that was supposed to meet the challenge of consolidating various different concepts and establishing generally valid characteristics, which he also published in 1965 as "Thoughts on a General Theory of Models." This work earned Stachowiak recognition within German cybernetic circles and beyond: in 1971, part of the article was translated in Spanish; and in 1972 Stachowiak directed a version translated into English to the UNESCO publication *Scientific Thought* (Stachowiak [1971] 1972). So, what is the content of this model theory?

3. The General Concept of the Model as Based in Cybernetics

The example of West Germany affirms the nascent popularity of the term "model"—and, more specifically, the evaluation of formal logic—in the mid-1960s. In 1965, the impressive tally of 23 articles appeared in the interdisciplinary journal *Studium Generale*, founded in 1947 and dedicated to the "unity of the sciences." With the exception of Herbert Stachowiak, the authors referred to their own disciplines, comparing them to others. Gert Müller discussed the origins of the model in mathematics and qualified any claim of universality by explaining that there were hardly any connections between the mathematical model and other "concepts of models and schemas" (Müller 1965, p. 164). Max Jammer addressed the change of the meaning of the model in physics. According to Jammer, it had lost its function as an "illustration," whereas with the emergence of quantum physics around 1900 it became central as a "criterion of logical freedom from contradiction." But its function as a "logical instrument of modern science" did not exclude other functions (Jammer 1965, p. 172). With regard to biology, Gernot Wendler argued that the "meaning of the word model" was not "bindingly determined." In his opinion, "model" was developing into a "vogue term." He surmised that "a vogue expression arises … if the concept's application area suddenly becomes topical or if the conceptual content is subject to rapid change." Thus he insisted that the model's enormous popularity at the time was based on a heightened sensitivity to its change of functions (Wendler 1965, p. 284).

Notably, a few authors criticized mathematics, explicitly questioning its use for the practice of social and human sciences and drawing striking conclusions. They emphasized alternatives to formal logic and its models, by which they meant a respective discipline's traditional, practicable, representation-theoretical, or functional concepts. Thus, according to Gottfried Bombach, economics featured a long tradition of model thinking, evident, for example, in the "thought template" of the economic cycle. Mathematics had started a "triumphal march in modern modeling," but "not every application of mathematics in economics already [involved] model analysis" (Bombach 1965, p. 339). The psychologist Wolfgang Metzger equated models with demonstrative hypotheses, noting "that one arrives at certain testable predictions not only on the basis of mathematical models." Restricting psychology to models derived from mathematics did not make sense, for it remained to be seen whether demonstrative or formal models would be more successful (Metzger 1965, p. 352). August Vetter similarly concluded that psychology was departing from the "atomistic fragmentation of psychic life" which set in around 1900. Gestalt psychology was in the first stage of "freeing psychological investigation from the spell of the physical mindset and regaining its independence" (Vetter 1965, p. 353). These statements by scientists from diverse fields illustrate a shift in the conception of the model combined with a critique of the (exclusive) use of formal logic and mathematical models. We cannot definitively confirm from the source material that the authors' choice of words was influenced by the dawning crisis of logical empiricism, reflected in Germany by the "positivism dispute"; but it conformed to the zeitgeist.

The development of the *General Model Theory* stood precisely against this background of a rejection of formal models that, from the perspective of hands-on researchers, proved inadequate for subjects of the social and human sciences. Herbert Stachowiak engaged in criticism as well, but did not invoke a traditional discipline-specific model concept; instead, he formulated a new supradisciplinary cognitive construct. In "Thoughts on a General Theory of Models," he maintained that the numerous efforts to grasp the meaning of the "model" followed from the increased importance of models, noting that the reason lies in a "deep-seated" change of "scientific-philosophical thought" (Stachowiak 1965b, p. 432). In line with the cybernetic jargon of renewal, he located this upheaval in the Second World War and advanced the thesis that philosophy no longer had any influence on the "sudden upward trend" of research. Rather, (neo-) empiricism and (neo-) positivism had become central, but they were merely precursors to far more sweeping developments. According to Stachowiak, both scientific-theoretical perspectives are in a "transition [to a] neopragmatic movement spreading increasingly over the world, taking place in which was the rediscovery of the anthropologically original function of science as an instrument for human coping with existence" (Stachowiak 1965b, p. 433). This movement, he argued, was characterized by heuristic liberality and an indifference with regard to verification theory: "Any path that leads to a scientific theory that is useful for the practical coping with existence is permitted." In turn, theories only had to fulfill a pragmatic usefulness criterion, namely, enabling purposeful and systematic action (Stachowiak 1965b, p. 434).

Even though Stachowiak did not explain his reasons choosing the term "neopragmatism," we can find three important references. First, by defining models as representatives of their (neither directly comprehensible nor visible) original (Stachowiak 1965b, p. 438), Stachowiak follows a semiotic understanding. In other words, his interpretation of the concept of the model corresponds to the two-sided character of epistemology as developed by Charles Sanders Peirce. His concept of science involves a reinterpretation of American pragmatism in the context of German circumstances, combined with a dissociation from continental European philosophy (exemplified by idealism, dialectical materialism, and existentialism) (Stachowiak 1965b, pp. 432–33). Second, Stachowiak's position is obviously cybernetically based: he makes a clear break between research before and after the Second World War and closely links knowledge to practical, progress-oriented application. As Michael Hagner has argued, it is precisely this amalgam of knowledge and implementation—*episteme* plus *techne*—that forms the central pillar of cybernetic theory (Hagner 2008, p. 39). Third, the notion that the success of science can logically be measured according to its purpose points to the logic of instrumentalism inherent to cybernetics.

> The neopragmatic concept of science now corresponds very narrowly with the model concept broadly used today in empirical research. … The increasing pragmatization of scientific thought … finds its characteristic expression in the growing tendency of scientists to describe numerous if not all cognitive constructs of modern experiential-scientific research as "models." (Stachowiak 1965b, p. 436)

As a consequence of the "neopragmatic concept," Stachowiak introduces a general concept of the model that, regardless of its relevance, is to be kept bare of content so as to be as all-encompassing as possible. This purpose requires the formulation of a concise catalogue of features that subsumes existing concepts (Stachowiak 1965b, p. 437). Thus in short, the general validity of the model builds on a disengagement from disciplinary thought and on a dearth of content. Following from Ludwig von Bertalanffy's *General System Theory*, the development of a general model theory necessitated a search for structural commonalities of method-related fields of knowledge in order to place them on the meta level (Stachowiak 1965b, p. 454).

Funded by the German Research Foundation (*Deutsche Forschungsgemeinschaft*), Stachowiak worked out his article about the concept and relevance of the model. He further honed his theses, setting them apart from other scientific-theoretical perspectives and thereby taking a clear position in favor of "experiential sciences." First, he explains that the semantic model concept of deductive mathematical logic, as formulated by Alfred Tarski, cannot be generalized. The term model must be grasped more broadly to include not only formal but also technical models, as well as models of empirical sciences and also heuristics (Stachowiak 1973, p. 3). The objection "against the transfer of the logical-semantic model concept to the experiential sciences" is that it "in no way does justice to widely practiced scientific linguistic usage." Instead, an appropriate general model concept must be derived from practical usage, that is, inductively (Stachowiak 1965b, pp. 1–4). With recourse to Karl Popper, Stachowiak then qualifies critical rationalism by rejecting the falsification principle with regard to the use of models. Models can be improved but not refuted; it is important to "comprehend de facto scientific progress from the specific manner of its realization ... and from this give methodological instructions on how future scientific progress can be ensured" (Stachowiak 1965b, p. 49). Hence the importance of the "decision" to create a model concept that is neopragmatically liberal in the sense of not impeding progress (Stachowiak 1965b, p. 51). According to Stachowiak, everything could be a model, from the most elementary perception to the most complicated theory, from metaphysics to the natural sciences (Stachowiak 1965b, pp. 56–7). In another text published in 1983, he enlarged his position that metaphysics was not only speculative and that the boundary between metaphysics and science was only established by convention (Stachowiak 1983). In this respect, his understanding of science became more nuanced in that it marked an accommodation of conventionalism.

However, Stachowiak was no longer able to build on his success with "Thoughts on a General Theory of Models" in 1965, which had coincided with the peak of cybernetics in Germany. Even though it dealt with the "great names" and concepts of scientific theory of the twentieth century, his overall work remained relatively unknown. It generated significant resonance only in German pedagogy, whose orientation toward action proved extremely compatible with the general model concept, which favors utility and irrefutability as opposed to theories that are difficult to grasp (Hof 2016).

Meanwhile, in 1999 the German Society of Cybernetics (*Deutsche Gesellschaft für Kybernetik*) honored Stachowiak for his work (Piotrowski 2010). By this time, however, cybernetics had drifted to the fringes of scientific debates and publications. Its fortunes had already collapsed in the late 1960s in both East and West Germany. For East Germany, the chief reason for this collapse is assumed to be the closing of the border to the West in connection with the Prague Spring. As in other Eastern Bloc states, after 1968 intellectuals were accused of "revisionism" if they referred to works by Western academics. Cybernetics lost acceptance and became suspected of criticizing the regime; by the time Erich Honecker took over the leadership of the SED, it was openly rejected (Segal 2004, p. 244). At the same time, in West Germany a growing rift had opened up between cybernetics' real technological potential for renewal and its reception in the media and scientific discourse, comparable to developments in the United States. As Ronald Kline (2015) concludes from the history of American cybernetics, it was never "one thing," despite the claims of some of its promoters. Similarly, in West Germany interdisciplinary committees may have shared technology oriented futuristic visions, but practical reception played out within existing disciplines (see Aumann 2009, 2011). Research money remained tied to institutional frameworks; to be sure, funding was announced for technological megaprojects, but not for metatheoretical projects (see Coy 2004). Cybernetics enhanced application-oriented research and became the basis for many technologies. Yet even though it was influential, cybernetics never became an overarching universal science.

Moreover, as Joseph Agassi (1995) has noted, there is no "theory of the model." Different kind of models, such as scale models, diagrams, mathematical formalisms, pictures, illustrations, and artifacts suit a range of functions. An all-encompassing and singular definition of the model does not exist; at most, there are similarities in the interpretation and application of models – despite the attempt by the German mathematician Bernd Mahr after the turn of the millennium to (once more) formulate a "model of model-being" (see Mahr 2004, 2008, 2015). Even though the general model theory tried to grasp models in general, a valid transdisciplinary concept failed to prevail in either the philosophy or practice of science. Instead, the consensus is that there is a wide spectrum of interpretations that have too little in common to justify a single substantively standardized perspective (see Hartmann 1995; Bailer-Jones 2002; Koperski 2006; Gelfert 2011; Frigg and Hartmann 2012).

Thus, neither the general model theory nor cybernetics engendered a lasting unifying method. The view of models as purpose specific and indifferent with regard to verification theory, however, seems widespread.

Without referring to Stachowiak, Jürgen Mittelstraß, for example, concluded: "Models [are] neither true nor false but rather strongly applicable or weakly applicable … They are determined by a *pragmatic* criterion, not a truth criterion" (Mittelstraß 2005). In his theory, Stachowiak evidently presented arguments that are shared by a larger research community; and this gives us reason, despite the theory's lack of prominence, to elucidate an aspect of the general model theory that illustrates how a change of epistemological-theoretical perspective resulted in the attribution of a new function and utility to the model concept. Stachowiak did not prefigure this change but, as an observer of scientific "linguistic usage," he recognized and formulated it in his own words.

4. Toward the Inclusion of the Interpreter

As elaborated above, the founding of the general model concept resulted from a critique of the reach of formal logic and its semantic model, which from the viewpoint of researchers in subareas of the social and human sciences did not have enough explanatory power. This conceptual crisis, reflected in the disputes of 1965 in the *Studium Generale*, foregrounded model functions that deviated from those of the classical concept of the model. One such function corresponds to a recent development that popularized the re-terming of the model as a "tool." As before, this shift in the concept of the model can be traced back to competing epistemological positions.

Besides diverging interpretations of the model, a main difference lies between the classical concept of formal logic, on the one hand, and pragmatic functional approaches, on the other hand. Although both concepts suggest the idea of models as representations, recent pragmatist positions define the "model" as an independent entity between two positions, in other words, as a "mediator" between the user and the object of inquiry (Morrison and Morgan 1999). Furthermore, in the wake of criticizing the concept of representation as proving "too limiting" on its own to understand the utility of models, Mike Boon and Tarja Knuuttila have elaborated the idea of models as "epistemic tools" (Boon and Knuuttila 2008, p. 694). The general model theory by Herbert Stachowiak is a precursor of this development, as evident from its three "pragmatic characteristics" of the model concept:

> Models are not only models of something. They are also models for someone. … A fully pragmatic determination of the model concept must consider not only the question as to what something is the model of, but also for whom, when, and what for. (Stachowiak 1973, p. 133)

The inclusion of the interpreter ("for whom") introduces new meaning that moves the model away from classical functions such as illustration, reduction, or analogy. The question about the subject adds a third position to the relationship between the model and phenomenon, or in Stachowiak's words: "We are the ones who design the modeling that emulates the originals" (Stachowiak 1973, p. 288). This foregrounded modeling as a varying and revisable process, instead of the model as a static product.

This expansion of the model concept to include the user and his interpretation should be seen as the result of the cognitive turn around 1970. As Roland Müller (Müller 2009, p. 651) noted, it is widely accepted that humans make sense of the world by forming internal representations. Yet this insight was neglected by behaviorism during its heyday in the first half of the twentieth century, which focused on external and visible consequences of behavior. Only in the course of the cognitive turn did the notion of mental representation become accepted again. This turn involved, among other things, making the mental performance of the modeling subject part of cognition per se. More specifically, the epistemological concept of constructivism called objectivity into question, namely, by interpreting cognition as a process that is distinct from its object and actively carried out by a subject (see von Foerster and von Glaserfeld 1999). This change dovetails with the full distinction of the instrumental importance of models: to be sure, it has always been widely accepted that models represent their phenomenon (whether these are axioms or biological processes), but now the focus shifted to the question of mediating between the phenomenon and the interpreter through the medium of the model, or, as claimed by Stachowiak: "All cognition is cognition in models or through models" (Stachowiak 1973, p. 56; 1980, p. 29). Although we still know remarkably little about the impact of the cognitive turn on philosophy of science, it is evident that the concept of the model acquired new meaning.

Tarja Knuuttila has also recently pragmatically qualified the model concept; and she, too, concluded that representation is characterized not so much by the "pure" determination of the relationship between model and phenomenon than by the fact that it must raise the question as to its utility (Knuuttila 2011, p. 266). Stachowiak's "neopragmatic" conception of the model, which insists on taking into account "for whom, when, and why" a model is created, should thus be seen as a precursor of today's characterization of the model as an "epistemic tool" or "useful instrument" to mediate between the user and the phenomenon under study. Even though the general model theory is not very well known and failed in its ambition to help create an all-encompassing model concept, it testifies to the change toward the "cognitive perspective" (Bailer-Jones 1999), which is particularly distinguished by the expansion of model functions to include a subject position and by an orientation to pragmatic criteria.

5. Concluding Remarks

Unifying science or epistemic change? In summary, we can conclude that concepts like the scientific model do not exist as supra-historical ideas but rather are subject to competing interpretations. Even though the superordinate figure of thought of the cybernetically based model concept could not prevail against the plurality of disciplinary interpretations and establish itself as a meta-concept, it exemplifies a consequential modification of the function of models. Nonetheless, despite the importance of "modeling" for cybernetic instrumentalism, the question of the impact of cybernetics on the reconceptualization process of the model must remain open, insofar as there are too many contradictions between the de facto lack of reception of its theoretical structure and the simultaneous turn to a (neo-) pragmatic, purpose-oriented cognitive theory, which cannot be imagined without the subject's involvement as the decision-maker regarding utility and the lack thereof.

With a view to the present, in closing it must be concluded that the interpretation of models as "tools" does not constitute a value-free addendum: instruments are subject to the risk of an implied neutrality that in fact is not neutral at all. If models do not merely depict and reduce, if they are not independent of the mental performance of construction, then models, on the one hand, are determined by human objectives and ideas and, on the other hand, possess the potential "to reshape social reality in a way that also affects human desires and interests" (Gelfert 2016, p. 116). If the world is mediated to us by instruments, we must be aware that these instruments pre-structure our perception. The role, significance, and function of models and modeling are thus far from being definitively elucidated.

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